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ABSTRACT

The muscle action potentials (MAP) of the anterior deltoid, pectoralis major, biceps brachii, and the triceps muscle were studied by quantitative electromyography (emg) during a bench press exercise at three controlled speeds. Bipolar surface electrodes with standard placement were employed throughout the study. Eleven volunteer college women performed three trials at each speed. All Ss were familiar with the exercise and the test procedures. Angles and hand grip were kept constant. Randomization of speed of contraction eliminated order effects, and no verbal motivation was provided. Rest was controlled to negate fatigue. An analysis of variance (ANOVA) and Duncan's Multiple Range Test were used to determine the significance of any differences obtained. Results indicated that the slower the speed of movement the greater the MAP output. In every instance, each slower speed produced a significantly greater MAP (P greater than .01) than the compared faster speed, except for the biceps brachii which exhibited the same trend but with no significance for the moderate speeds. (Author/JB)

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AN ELECTROMYOGRAPH COMPARISON OF AN ISOKINETIC BENCH PRESS AT THREE SPEEDS

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INTRODUCTION

Isokinetic exercise offers a new dimension in resistive exercise technique. Of the three types of muscle contraction---isometric, isotonic, and isokinetic---isokinetic is thought to have the advantage of better controlling the muscle loading. Force is not sacrificed when controlling the speed of the contraction. Through isokinetics the muscle is believed to be more accurately loaded to its fullest capacity (Hislop and Perrine, 1967).

Isokinetic contraction is dynamic in nature as is isotonic contraction but differs from isotonic in the fact that maximum resistance may be maintained throughout the entire range of motion. The contraction is performed at a predetermined and controlled rate of speed that cannot be exceeded regardless of the force applied (Thistle et al., 1967).

The isokinetic method attempts to elicit maximum volitional muscular involvement at every point along a full range of motion (Hislop and Perrine, 1967). With isokinetic exercise the accomodating resistance of the exercise apparatus matches the user's immediate muscular capacity whether it is the first or fifth repetition. Because the isokinetic apparatus allows for the control of the speed of the exercise the weight resistance is controlled. It automatically accomodates to the body part as it moves throughout a complete

range of motion (Spackman, 1971). If a maximum effort is given, the quantitative involvement of motor units during an isokinetic contraction will vary according to the regulated speed of the contraction which is controlled by the isokinetic exercise apparatus and the effort of the subject. The slower speeds are designed for strength building while the faster speeds are designed for developing endurance. (Henson, 1972)

Although several studies (Thistle et al., 1967; Moffroid et al., 1969; Rosentswieg and Hinson, 1972; Hinson and Rosentswieg, 1972) have been completed investigating comparative strength gains of isometric, isotonic, and isokinetic contractions, no investigation has been found that has studied the quantitative muscular involvement of isokinetic contractions performed at different speeds independently of other concepts of exercise. It was the purpose of this study to investigate the muscular involvement of the anterior deltoid, pectoralis major, biceps brachii, and triceps muscles elicited by an isokinetic bench press exercise performed at three controlled speeds through statistical analysis of quantitative electromyographic data.

STATEMENT OF THE PROBLEM

The problem selected for this study was to determine if any statistically significant differences at the .01 level existed between the muscle action potentials elicited by the anterior deltoid, pectoralis major, biceps brachii, and

triceps muscles during an isokinetic bench press performed at three speeds of contraction by three different pulley systems. The isokinetic bench presses were performed on the Super Mini Gym, Model #130, manufactured by the Mini-Gym, Incorporated of Independence, Missouri.

The following null hypothesis was tested:

There is no significant difference between the three speeds of isokinetic bench press contractions of the anterior deltoid, pectoralis major, biceps brachii, and triceps muscles with respect to muscle action potential values as measured by integrated electromyographic equipment.

DELIMITATIONS OF THE STUDY

The study was subject to certain delimitations. The selected techniques used to collect and measure the isokinetic contractions and muscle action potentials in each subject were delimitations in that the actual speed of the contraction was an approximation and the actual poundage recorded at any instant was unknown. The eleven college women (N=11) between the ages of 18 and 22 ($\bar{X}$=19) who were enrolled at the Texas Woman's University during the academic year of 1971-1972 and who participated in the study were delimitations in that the number of subjects in the study was small and all the subjects were college age females.

REVIEW OF RELATED LITERATURE

Thistle et al., 1967, conducted a clinical pilot

study investigating the benefits of accomodating resistive exercise and isometric exercise in the left quadriceps femoris muscle. Sixty subjects were divided into three exercise and one non-exercise groups. The exercise groups exercised four days a week and were tested on the isokinetic apparatus (Cybex isokinetic exerciser) on the fifth day. Torque curves were recorded over the eight week exercise period. Comparisons were made between the scores from the first two weeks and the final two weeks. The scores (total work and maximum force exerted scores) were analyzed and percentage increments calculated. The group receiving the accomodating resistive exercise scored higher than the other groups. The investigators concluded that accomodating resistive exercise offers a new approach to muscular exercise and analysis.

Moffroid et al., 1969, attempted to compare the increases of muscular torque in the quadriceps and hamstrings after four weeks of isometric, isotonic, and isokinetic exercise. Sixty subjects were randomly assigned to three groups---isometric, isotonic, or isokinetic. All subjects exercised (knee extensions) for four weeks and were tested once daily for strength on the isokinetic device. The isometric group performed ten maximum holds at a 90° and 45° angle of knee flexion. The isotonic group performed three series of ten repetitions of knee extension. The isokinetic group performed thirty maximum repetitions daily. The subjects in the isotonic group increased muscle torque of the quadriceps at a 45° angle more so than at a 90° angle. There was a

significant increase of work output of the isokinetic group. The peak torque of the quadriceps occurred at 63 ± 4^{o}, and the peak torque of the hamstrings occured at 34 ± 2^{o}. The isometric group showed significant increases of work output in the quadriceps and hamstrings at both 90^{o} and 45^{o}. Neither the isotonic or isometric group showed a significant increase when tested weekly on the isokinetic exerciser.

Rosentswieg and Hinson, 1972, conducted a study investigating the relationships between isometric, isotonic, and isokinetic contractions of the biceps brachii muscle at different angles of elbow flexion in thirteen female subjects. Integrated electromyographic data were recorded as a simultaneous film record of each contraction was made. The results of an analysis of variance revealed that the greatest muscle action potential was yielded by the isokinetic contractions. This finding was significant at the .10 level. There was no significant differences found among the various angles in terms of muscle action potential elicited during the isometric or isokinetic contractions. During an isotonic contraction the muscle action potential elicited with the elbow fully flexed was significantly smaller than the other angles studied. The investigators concluded that isokinetic work appears to be the preferred type of exercise for the development of strength in the biceps brachii.

DeLateur et al., 1972, studied the effectiveness of isokinetic and isotonic exercise in strength development of the quadriceps. Forty-four subjects were randomly di-

vided into four groups. Group 1 trained on weights; Group 2 trained on the Cybex isokinetic exerciser; Group 3 trained on the weights and shifted to the Cybex; and Group 4 trained on the Cybex and shifted to the weights. The subjects were asked to exercise (leg kicks) until fatigue which had been predetermined by pilot studies. The subjects were paid by the repetition and completed twenty-six training sessions. The rate of contraction and range of motion were kept constant. There were no significant differences between any of the groups with respect to the method by which they were trained. It was suggested that the Cybex isokinetic exerciser offered no particular advantage for strengthening the quadriceps.

In an investigation by Hinson and Rosentswieg, 1972, a study of the relationship between isokinetic, isotonic, and isometric contractions was conducted on fifty-two college women. Electromyographic data were collected from the biceps brachii and rectus femoris muscles of each subject. Isotonic and isokinetic contractions were begun at 90° flexion and continued to full extension at 180°. Isometric contractions were performed at 120° of knee flexion. The results of their findings indicated that no single method of muscular contraction elicited the greatest muscle action potential for every subject. The investigators suggested that subjects should be classified according to motor unit involvement of the specific muscle in question for the three types of contraction before placing them in various strength programs.

PROCEDURES FOLLOWED IN THE DEVELOPMENT OF THE STUDY

Bipolar surface electrodes were used throughout the study. Placement of the electrodes on the anterior deltoid, pectoralis major, biceps brachii, and triceps muscles was in accordance with procedures outlined by Davis (1959). Skin preparation, which consisted of rubbing the skin placement area with alcohol and then lightly sanding with a fine grade of sandpaper, allowed an impedance level of less than 5000 ohms which is the maximum acceptable impedance level for the equipment used (deVries, 1966).

The electromyographic data were obtained through the use of two Newport Laboratories Integrated Bioelectric Monitors, Model 100, which are capable of measuring to the one microvolt second level. The Bioelectric Monitor, a "quiet" amplifier which incorporates a voltage controlled oscillator, integrates the muscle action potentials and sends, to the electronic digital counter, the data in V_p elicited by a muscular contraction, divided by time (uVsec). Detailed information of the equipment has been presented by deVries (1965).

Calibration of the equipment was made prior to and after all of the measurements by introducing an impulse of known value from a microvolter and a low frequency generator. The procedure used to record the integrated data in uVsec required that the digital counter be activated as the subjects began each contraction, and stopped at the completion of each of the contractions. The digital read-out represented,

therefore, a cumulation of the muscle action potentials which were elicited by the specific bench press exercise.

Each subject was oriented to the equipment prior to the testing period. The bench press exercise was performed by each subject with the hands in a pronated position with the elbow flexed in a 30° angle. The subjects performed three trials at each speed on the Super Mini Gym, Model #130, isokinetic bench press apparatus. The three speeds were regulated by a no pulley, a one pulley, and a two pulley attachment system. The speeds of the bench contractions of the various pulley systems were approximately 1.5 seconds/3 feet for the no pulley attachment; 2 seconds for the one pulley attachment; and 3.5 seconds for the two pulley attachment. These settings were designated as the following: Setting A-no pulley (1.5 seconds); Setting B-one pulley (2 seconds); and Setting C-two pulley (3.5 seconds). The three bench press trials at each setting were averaged and a mean value was obtained for each subject at each speed setting. The no pulley attachment was attained through the use of the Super Mini Gym Achiever Model, Model #300T which had its rope (the handle was removed) attached to the connection on the bench press bar of the Super Mini Gym, Model #130.

All angles of elbow flexion were measured with a goniometer and care was taken to maintain a constant hand grip position and muscular isolation to the specific muscles involved. Isokinetic contractions were begun at a 30° angle of elbow flexion and continued to full extension at 180°.

Each subject performed a maximum effort for each bench press. No verbal motivation was given. The order of the three different bench press contractions at the three speed settings was randomized and adequate rest was provided to prevent any fatigue effects.

FINDINGS OF THE STUDY

The integrated electromyographic data were treated statistically by the application of a one-way analysis of variance for each of the muscles studied. Subsequent Duncan's Multiple Range Tests were computed when significant F ratios were found in the analysis of variance computations.

Table 1 shows the results of the application of the analysis of variance to the electromyographic data from the anterior deltoid muscle. Table 1 indicated that the differences between the muscle action potentials elicited by the three settings were significant ($P<.01$).

TABLE 1

ANALYSIS OF VARIANCE FOR MAPS ELICITED BY THE ANTERIOR DELTOID DURING THREE BENCH PRESS CONTRACTIONS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Between	2	222,707,417.455	111,353,708.728	60.982*
Within	30	54,779,959.090	1,825,998.536	
Total	32	277,487,376.545		

$F_{2,30}(.01)=5.39$

TABLE 2

DUNCAN'S MULTIPLE RANGE TEST APPLIED TO THE MEANS OF THE THREE BENCH PRESS CONTRACTIONS OF THE ANTERIOR DELTOID

		Setting A	Setting B	Setting C	K	R
		2922.46	5005.55	9171.18		
Setting A	2922.46		2083.09*	6248.72*	3	1652.86
Setting B	5005.55			4165.64*	2	1584.81

*Significant at the .01 level.

Table 2 reveals the results of the Duncan's Multiple Range Test which was a necessary subsequent test to determine which setting elicited the highest muscle action potentials in the anterior deltoid muscle. The results indicated that Setting C (slowest contraction time) elicited significantly higher MAPS than either Setting B or Setting A (fastest contraction time). Setting A elicited the lowest values of all three speed settings.

Table 3 (page 11) reveals the results of the ANOVA applied to the data elicited by the pectoralis major muscle. A significant F value of 28.709 indicated that there were differences between the MAPS elicited by the pectoralis major muscle at the three contraction speed settings of the bench press exercise. A Duncan's Multiple Range Test (Table 4 on page 11) was applied to the mean differences to establish where these differences were significant. Setting C again yielded significantly higher MAP values than either Setting B or Setting A while Setting B's values were significantly

higher than setting A.

TABLE 3

ANALYSIS OF VARIANCE FOR MAPS ELICITED BY THE PECTORALIS MAJOR DURING THREE BENCH PRESS CONTRACTIONS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Between	2	274,736,519.697	137,368,259.849	28.709*
Within	30	143,555,369.818	4,785,178.994	
Total	32	418,291,889.515		

$F_{2,30}$ (.01)=5.39

TABLE 4

DUNCAN'S MULTIPLE RANGE TEST APPLIED TO THE MEANS OF THE THREE BENCH PRESS CONTRACTIONS OF THE PECTORALIS MAJOR

		Setting A	Setting B	Setting C	K	R
		2563.55	4776.73	9483.09		
Setting A	2563.55		2213.18*	6919.54*	3	2675.66
Setting B	4776.73			4706.36*	2	2565.50

*Significant at the .01 level.

Table 5 (page 12) indicated that there were significant differences between the MAP values of the three contraction speed settings with respect to the triceps muscle as represented by an F value of 159.738 ($p<.01$). The follow up Duncan's Test shown in Table 6 (page 12) showed the identical results as did the pectoralis major and anterior deltoid muscles.

TABLE 5

ANALYSIS OF VARIANCE FOR MAPS ELICITED BY THE TRICEPS DURING THREE BENCH PRESS CONTRACTIONS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Between	2	225,799,216.545	112,899,608.273	159.738*
Within	30	21,203,412.000	706,780.400	
Total	32	247,002,628.545		

$F_{2,30}$ (.01)=5.39

TABLE 6

DUNCAN'S MULTIPLE RANGE TEST APPLIED TO THE MEANS OF THE THREE BENCH PRESS CONTRACTIONS OF THE TRICEPS

		Setting A	Setting B	Setting C	K	R
		2738.18	4916.27	9045.73		
Setting A	2738.18		2178.09*	6307.55*	3	1028.32
Setting B	4916.27			4129.46*	2	985.98

*Significant at the .01 level.

Table 7 (page 13), the analysis of variance applied to the electromyographic data elicited by the biceps brachii muscle revealed that significant differences existed between the three speed settings of the isokinetic bench press contraction. Table 8 (page 13), a Duncan's Multiple Range Test, indicated that Setting C elicited significantly higher MAP levels than

either Setting A or Setting B. No other significant differences were found.

TABLE 7

ANALYSIS OF VARIANCE FOR MAPS ELICITED BY THE BICEPS BRACHII DURING THREE BENCH PRESS CONTRACTIONS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Between	2	25,174,404.182	12,587,202.091	21.45*
Within	30	17,606,659.454	586,888.649	
Total	32	42,781,063.636		

$F_{2,30}$ (.01)=5.39

TABLE 8

DUNCAN'S MULTIPLE RANGE TEST APPLIED TO THE MEANS OF THE THREE BENCH PRESS CONTRACTIONS OF THE BICEPS BRACHII

		Setting A	Setting B	Setting C	K	R
		1394.18	2041.18	3483.73		
Setting A	1394.18		647.00	2089.55*	3	922.58
Setting B	2041.18			1442.55*	2	884.60

*Significant at the .01 level.

SUMMARY OF THE FINDINGS

The electromyographic data were treated by a simple

one-way analysis of variance for each specific muscle studied. These muscles included the anterior deltoid, pectoralis major, biceps brachii, and triceps. Tables 1, 3, 5, and 7 show the results of the ANOVAS. Subsequent Duncan's Multiple Range Tests (Tables 2, 4, 6, and 8) were performed because each of the ANOVA's revealed a significant F value which indicated that there were significant differences between the three speed settings. All of the Duncan's Multiple Range Tests revealed that Setting C (slowest contraction time) yielded significantly higher MAP levels than either Setting B or Setting A in each of the four muscles studied. Setting B yielded significantly higher values than Setting A with respect to the anterior deltoid, pectoralis major, and triceps muscles. In the study of the biceps brachii muscle the Duncan's Test indicated that there were no significant differences between Setting B and Setting A.

DISCUSSION AND CONCLUSION

The present investigation entailed a study of the differences between the muscle action potentials elicited by the anterior deltoid, pectoralis major, biceps brachii, and triceps muscles during an isokinetic bench press performed at three speeds of contraction controlled by three different pulley systems. Eleven college women participated in the study. Electromyographic data were collected through the use of two Newport Laboratories Integrated Bioelectric Monitors. To determine if there were any significant dif-

ferences between the three contraction speeds for each of the muscles studied, a simple one way analysis of variance was applied to the data. When significant differences were found, a Duncan's Multiple Range Test was used to determine where the differences existed.

The following finding was obtained from the study:

There were significant differences between the three speeds of isokinetic bench press contractions of the anterior deltoid, pectoralis major, biceps brachii, and triceps muscles with respect to muscle action potentials. As a result of this finding, the investigator rejected the null hypothesis at the .01 level.

It may be concluded that the slower the speed of the isokinetic bench press contraction, the greater the muscle action potentials elicited by the specific muscles studied. Instrument Setting C (slowest contraction time) consistently had significantly higher muscle action potential levels than either of the other settings. The next slowest speed (Setting B) elicited significantly higher muscle action potentials than Setting A with respect to the anterior deltoid, pectoralis major, and triceps muscles. In the analysis of the biceps brachii the second slowest speed (Setting B) yielded higher values than Setting A, but this was not significant.

To facilitate the interpretation of the relative MAP value for each of the three speed settings, the data were converted to a constant time value. Tables 9 through 16 present ANOVA and Duncan's Multiple Range Test results for each muscle group considered in terms of the quantitative electromyographic data collected. The data represents a mean value of MAPS per second for each speed setting.

Table 9 indicated that the differences between the muscle action potentials of the anterior deltoid muscle elicited by the three settings were significant ($p < .05$). Table 10 revealed that Settings B (2.0 seconds) and C (3.5 seconds) elicited significantly higher MAPS than Setting A (1.5 seconds). There were no other significant differences.

TABLE 9

ANALYSIS OF VARIANCE FOR MAPS ELICITED BY THE ANTERIOR DELTOID DURING THREE BENCH PRESS CONTRACTIONS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Between	2	2,205,104.904	1,102,552.452	3.943*
Within	30	8,388,758.096	279,625.270	
Total	32	10,593,863.000		

$F_{2,30}(.05)=3.32$

Table 11 also indicated significant differences between the elicited muscle action potentials of the pectoralis major muscle. Table 12 revealed that Setting C yielded significantly higher MAP values than Setting B and Setting A.

TABLE 10

DUNCAN'S MULTIPLE RANGE TEST APPLIED TO THE MEANS OF MAPS ELICITED BY THREE BENCH PRESS CONTRACTIONS OF THE PECTORALIS MAJOR

		Setting A	Setting B	Setting C	K	R
		2020.36	2503.00	2616.64		
Setting A	2020.36		482.64*	596.28*	3	483.90
Setting B	2503.00			113.64	2	460.46

*Significant at the .05 level.

TABLE 11

ANALYSIS OF VARIANCE FOR MAPS ELICITED BY THE PECTORALIS MAJOR DURING THREE BENCH PRESS CONTRACTIONS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Between	2	4,309,478.700	2,154,739.350	33.316*
Within	30	19,402,503.000	64,675.000	
Total	32	23,711,981.700		

$F_{2,30}$ (.05)=3.32

Table 13 revealed significant differences between the MAP values of the three contraction speed settings with respect to the triceps muscle. Table 14 indicated that Settings B and C yielded significantly higher MAP values than Setting A. There were no other significant differences.

Table 15 yielded no significant differences between the three contraction speed settings with respect to the

biceps muscle. Table 12 reveals that Setting B yielded significantly higher MAP values than either Setting C or Setting A. There were no other significant differences.

TABLE 12

DUNCAN'S MULTIPLE RANGE TEST APPLIED TO THE MEANS OF THE THREE BENCH PRESS CONTRACTIONS OF THE PECTORALIS MAJOR

		Setting A	Setting B	Setting C	K	R
		1835.27	2393.27	2709.36		
Setting A	1835.27		558.00*	874.09*	3	232.72
Setting B	2393.27			316.09*	2	221.45

*Significant at the .05 level.

TABLE 13

ANALYSIS OF VARIANCE FOR MAPS ELICITED BY THE TRICEPS DURING THREE BENCH PRESS CONTRACTIONS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Between	2	3,638,436.192	1,819,218.096	17.315*
Within	30	3,151,906.008	105,063.534	
Total	32	6,790,342.200		

$F_{2,30}$ (.05)=3.32

TABLE 14

DUNCAN'S MULTIPLE RANGE TEST APPLIED TO THE MEANS OF THE THREE BENCH PRESS CONTRACTIONS OF THE TRICEPS

		Setting A	Setting B	Setting C	K	R
		1825.55	2458.36	2584.46		
Setting A	1825.55		632.81*	758.91*	3	296.61
Setting B	2458.36			126.10	2	282.24

*Significant at the .05 level.

TABLE 15

ANALYSIS OF VARIANCE FOR MAPS ELICITED BY THE BICEPS BRACHII DURING THREE BENCH PRESS CONTRACTIONS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Between	2	389,047.514	194,523.757	2.902
Within	30	2,010,779.826	67,025.994	
Total	32	2,399,827.340		

$F_{2,30}$ (.05)=3.32

TABLE 16

DUNCAN'S MULTIPLE RANGE TEST APPLIED TO THE MEANS OF THE THREE BENCH PRESS CONTRACTIONS OF THE BICEPS BRACHII

		Setting A	Setting C	Setting B	K	R
		778.82	995.36	1020.82		
Setting A	778.82		216.54	242.00*	3	236.91
Setting C	995.36			25.46	2	225.44

*Significant at the .05 level.

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